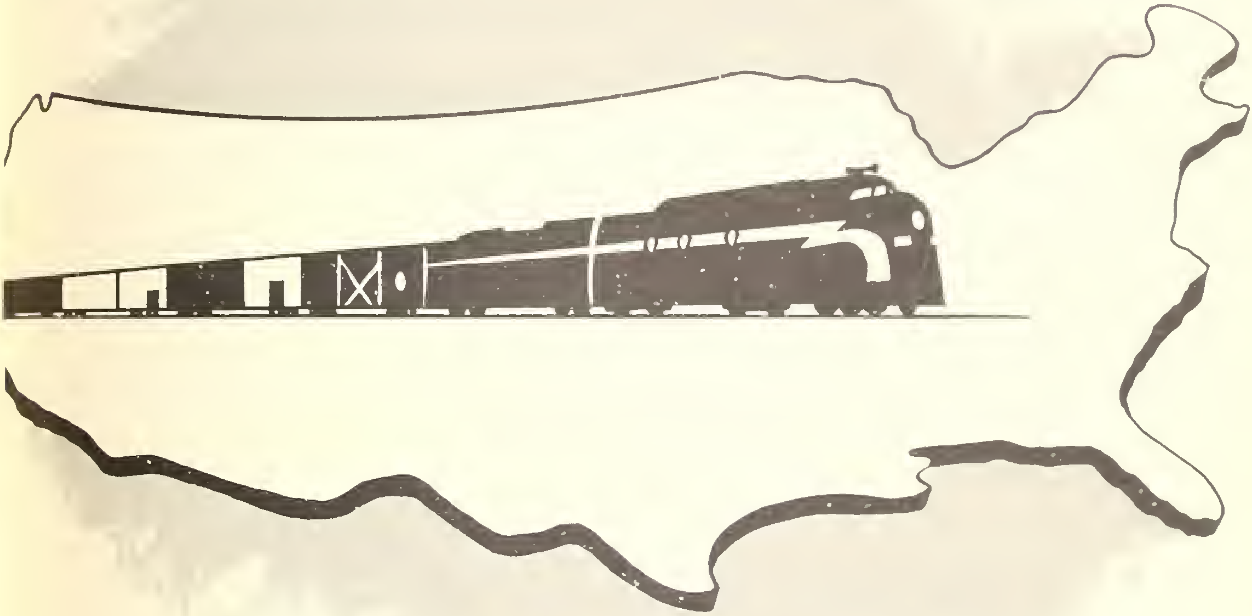
Transit Temperatures of CALIFORNIA LETTUCE



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TRANSIT TEMPERATURES OF CALIFORNIA LETTUCE

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SUMMARY AND CONCLUSIONS

Studies of transit temperatures and market quality of vacuum-cooled, dry-packed lettuce in rail shipments from Salinas, Calif., to New York City by rail show that--

1. Standard refrigeration with 2 percent initial salt and 3 percent salt at each re-icing provided adequate protection for well-precooled lettuce shipped during warm weather. The importance of good precooling was demonstrated. Heavy salting to offset relatively high initial lettuce temperatures resulting from insufficient precooling would increase the danger of freezing the lettuce in the normally cold parts of the load without materially reducing the temperature in the warmer positions.

2. A heavy load of nearly 33,000 pounds of lettuce in a 40-foot car carried well under standard refrigeration and a 2 and 3 percent salting schedule. Heavy loads of approximately 40,000 pounds carried well in 50-foot mechanical refrigerator cars.

3. Chimney loading of lettuce cartons had no advantage over well-alined on-side loading in regard to damage to the container, transit temperature, or condition of the lettuce at the market.

4. Lettuce carried well in either wirebound crates or cartons. The slight freezing that occurred in wirebound crates in the bottom layer of the load near the ice bunker when a 2 and 3 percent salting schedule was used indicates that lighter salting might be advisable for well-precooled lettuce shipped in this container.

5. Thermostatic control of temperatures in ice-bunker electric fan cars provided a margin of safety with respect to freezing when a heavy salting schedule of 3 and 5 percent was used. The action of dampers placed in the fan openings retarded temperature drops as a result of convection during prolonged train stops, and presumably had the same effect in transit during periods when the fans were inactivated by the thermostat.

6. Lettuce carried well in mechanically refrigerated cars of the envelope design. Air circulation from fans installed in the load compartment held transit temperature of the lading at a safe level and reduced condensation of moisture on the walls and ceiling of the car.

7. Relative humidity of the air above loads of lettuce while in transit averaged 73 percent in an ice-bunker car receiving 3 and 5 percent salt, and 90 percent in the mechanically refrigerated car equipped with air-circulating fans. No appreciable wilting of leaves occurred in either car.

8. Differences in general appearance, marginal browning, decay, or russet spotting of lettuce shipped at average temperatures that ranged from 34° to 42° F. could not be detected on arrival at the market, but lettuce shipped at temperatures in the lower part of this range had a longer shelf life than that shipped above 40°.

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[1] Horticulturist, associate horticulturist, senior plant pathologist, and associate pathologist, respectively.

[2] Olericulturist and extension marketing technologist, respectively.

BACKGROUND

The ideal temperature for maintaining quality in lettuce during marketing is 32° F. As the temperature rises above this optimum, soft rot decay increases, physiological disorders such as russet spotting[3] appear, and aging from natural respiratory processes is accelerated. When western lettuce is shipped to eastern markets, the time spent in transit accounts for most of the period between harvest and consumption. Significant departures from the optimum temperature that result from inadequate precooling of the lettuce or from insufficient refrigeration in transit and at the market can cause substantial wastage.

The development of new railway equipment makes testing desirable to determine the effectiveness of the equipment in providing suitable transit temperatures. Multipurpose, mechanically refrigerated cars and ice-refrigerated cars equipped to give thermostatically controlled temperatures are now being constructed. Some are already available to shippers of perishable commodities.

For these reasons, an accompanied lettuce transportation test was conducted from California to New York City in August 1957 to determine the effect of salting practices, size of load, pattern of loading, type of container, and type of railway equipment on transit temperatures of uniformly precooled lettuce. Studies were also conducted to relate the transit temperatures obtained in these tests to disorders and quality of the lettuce on the market. The studies are part of a broad program of continuing research designed to reduce the cost of marketing farm products.

PROCEDURE

The test was arranged in such a way that when one factor was being studied all other variables in the test were comparable. For example, when 3 different types of salting were tested, each of the 3 cars had a load of the same size, the same load pattern, the same type of container, and the same type of railway equipment; only salting differed.

Nine ice-bunker and 2 mechanically refrigerated railroad cars were loaded with vacuum-cooled head lettuce at Salinas, Calif. The ice-bunker cars were all equipped with electric air-circulating fans. All the lettuce was packed in cartons except one load packed in wirebound crates. The lettuce in cartons was vacuum-cooled before loading into the cars, while that in the wirebound crates was cooled after loading by means of a large vacuum cooler capable of holding an entire refrigerator car. All the ice-bunker cars were shipped under standard refrigeration.

Transit temperatures, taken with electrical resistance thermometers inserted into lettuce heads during loading, were obtained in the bottom, middle, and top layers of the loads along the centerline of the car at the bunker, quarterlength, and doorway positions, and also in the three layers adjacent to one wall at the quarterlength position. During most stops in transit, these distant-reading thermometers were read from the outside of the cars by members of the test party accompanying the train. In addition to these 12 positions, temperatures of the air blast and the air under the floor racks in certain cars were obtained with recording thermometers. The record of the various stops made in transit is shown in table 1.

Relative humidity in certain test cars was taken during transit to compare the relative effect of ice and mechanical refrigeration on air moisture. These measurements were made with an electric hygrometer that could be read from outside the car.

A hydrometer was used to take salinity readings on the drain water from certain cars in an attempt to determine the rate of depletion of salt from the ice bunkers.

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[3] Rood, Paul. Relation of ethylene and post-harvest temperature to brown spot of lettuce. Proc. Amer. Soc. Hort. Sci. 68: 296-303. 1956.

Table 1.--Trip log, Salinas, Calif., to New York, N. Y., August 1957

Date Aug.	Station	Miles X to X	Arrive	Depart	Standing time		Outside temperature	
			PST	PST	*Hr.*	*Min.*	*Time*	°F.
6	Salinas, Calif.	X	--	8:50 p.m.	--	--	2:00 p.m.	65
	Elkhorn		9:10 p.m.	9:40 p.m.	0	30	--	--
	Watsonville Junction		10:00 p.m.	11:25 p.m.	1	25	10:00 p.m.	58
7	San Jose	219	1:30 a.m.	2:25 a.m.	0	55	--	--
	Oakland		3:40 a.m.	4:40 a.m.	1	0	--	--
	Davis		6:50 a.m.	7:20 a.m.	0	30	7:00 a.m.	67
	Sacramento		7:40 a.m.	8:00 a.m.	0	20	--	--
	Roseville	X	9:00 a.m.	11:45 a.m.	2	45	11:00 a.m.	83
	M.P. 113		12:10 p.m.	12:20 p.m.	0	10	--	--
	Tunnel 28		1:15 p.m.	1:35 p.m.	0	20	--	--
	Dutch Flat	138	2:40 p.m.	3:00 p.m.	0	20	--	--
	Immigrant Gap		4:10 p.m.	4:40 p.m.	0	30	4:30 p.m.	68
	Norden		6:00 p.m.	6:15 p.m.	0	15	6:00 p.m.	62
	Sparks, Nev.	X	8:00 p.m.	9:25 p.m.	1	25	--	--
8	Imlay		12:15 a.m.	12:40 a.m.	0	25	12:30 a.m.	63
	Rose Creek	289	1:20 a.m.	1:35 a.m.	0	15	5:00 a.m.	54
	Winnemucca		1:50 a.m.	2:20 a.m.	0	30	--	--
	Barth		4:35 a.m.	5:20 a.m.	0	45	--	--
	Carlin	X	6:00 a.m.	6:30 a.m.	0	30	6:00 a.m.	58
	Wells		9:10 a.m.	9:20 a.m.	0	10	4:30 p.m.	93
	Pequop		10:35 a.m.	10:50 a.m.	0	15	10:50 a.m.	80
	Montello	249	11:50 a.m.	12:45 p.m.	0	55	--	--
	Pigeon		1:30 p.m.	4:50 p.m.	3	20	--	--
	Lemay		5:25 p.m.	5:45 p.m.	0	20	--	--
			MST	MST				
8	Ogden, Utah	X	9:15 p.m.	2:15 a.m.	5	0	10:00 p.m.	75
9	Echo		3:35 a.m.	3:45 a.m.	0	10	--	--
	Wahsatch	176	4:45 a.m.	5:05 a.m.	0	20	--	--
	Evanston, Wyo.		5:20 a.m.	5:30 a.m.	0	10	5:30 a.m.	47
	Green River	X	7:55 a.m.	9:40 a.m.	1	45	8:30 a.m.	70
	Bitter Creek	134	11:05 a.m.	11:18 a.m.	0	13	--	--
	Wamsutter		12:06 p.m.	12:24 p.m.	0	18	--	--
	Rawlins	X	1:50 p.m.	2:00 p.m.	0	10	2:00 p.m.	84
	Medicine Bow	116	3:23 p.m.	3:40 p.m.	0	17	--	--
	Rock River		4:18 p.m.	5:14 p.m.	0	56	5:00 p.m.	84
	Laramie	X	6:25 p.m.	7:25 p.m.	1	0	6:30 p.m.	75
	Cheyenne		10:20 p.m.	11:00 p.m.	0	40	--	--
10	Sidney, Nebr.	282	1:25 a.m.	1:40 a.m.	0	15	--	--
	Julesburg		1:50 a.m.	2:00 a.m.	0	10	--	--
			CST	CST				
	North Platte	X	6:00 a.m.	6:55 a.m.	0	55	6:00 a.m.	70
	Grand Island	284	9:55 a.m.	10:16 a.m.	0	21	11:00 a.m.	82
	Valley		12:45 p.m.	1:00 p.m.	0	15	1:00 p.m.	83
10-11	Council Bluffs, Iowa	X	1:55 p.m.	8:40 a.m.	18	45	6:30 a.m.	72
11	By Perry	122	11:40 a.m.	11:45 a.m.	0	5	11:45 a.m.	88
	By Atkins	X	2:30 p.m.	2:35 p.m.	0	5	2:30 p.m.	92
	By Oxford Junction	103	4:10 p.m.	--	0	0	4:10 p.m.	92
	Savanna, Ill.	X	5:30 p.m.	8:05 p.m.	2	35	5:30 p.m.	88
	Rockford	121	9:35 p.m.	10:05 p.m.	0	30	10:00 p.m.	74
11-12	Bensonville	X	11:59 p.m.	1:30 a.m.	1	30	12:10 a.m.	72

Table 1.--Trip log, Salinas, Calif., to New York, N. Y., August 1957--Continued

Date Aug.	Station	Miles X to X	Arrive	Depart	Standing time Hr.	Standing time Min.	Outside temperature Time	Outside temperature °F.
			CST	CST				
12	Blue Island		4:00 a.m.	10:00 a.m.	6	0	9:30 a.m.	78
	Cal - Park	92	10:15 a.m.	10:20 a.m.	0	05	--	--
	New Buffalo		11:35 a.m.	12:20 p.m.	0	45	11:40 a.m.	82
			EST	EST				
	Niles, Mich.	X	1:20 p.m.	3:45 p.m.	1	25	3:00 p.m.	93
	Jackson	75	6:30 p.m.	6:42 p.m.	0	12	6:30 p.m.	76
	Detroit	X	8:30 p.m.	9:05 p.m.	0	35	--	--
	Windsor, Canada	112	10:00 p.m.	11:15 p.m.	1	15	--	--
13	En route		1:25 a.m.	1:30 a.m.	0	05	--	--
	St. Thomas	X	1:40 a.m.	1:55 a.m.	0	15	1:50 a.m.	55
	En route		4:00 a.m.	4:15 a.m.	0	15	--	--
	Montrose	146	4:50 a.m.	4:55 a.m.	0	05	--	--
			5:10 a.m.	5:20 a.m.	0	10	--	--
	Bridge		6:15 a.m.	--	--	--	--	--
	Buffalo, N. Y.	X	6:30 a.m.	8:10 a.m.	1	40	6:30 a.m.	55
	Rochester	161	10:30 a.m.	10:50 a.m.	0	20	10:30 a.m.	75
	Wayneport		11:30 a.m.	12:15 p.m.	0	45	11:30 a.m.	73
	Syracuse	X	2:20 p.m.	(Hump at De Witt)	1	0	--	--
	De Witt	142	3:20 p.m.	5:45 p.m.	2	25	5:00 p.m.	75
	Oneida		6:25 p.m.	6:35 p.m.	0	10	--	--
	Utica		7:15 p.m.	7:30 p.m.	0	15	--	--
	Albany	X	10:10 p.m.	10:30 p.m.	0	20	--	--
14	New York City	140	2:30 a.m.	--	--	--	2:30 a.m.	69

Twenty-two packages of lettuce (Great Lakes type) harvested from a single field were used to determine the effect of transit temperature on condition at the market. Two packages were placed in each car in the middle layer of the load at the centerline, near the doorway and adjacent to a position at which transit temperatures were taken. One-half of the test lettuce from each car was examined upon arrival in New York and the other half was examined after a subsequent holding period of 3 days at 70° F. Similar lots were held at Davis, Calif., under simulated transit conditions of time and temperature.

FACTORS STUDIED AND THEIR EFFECTS ON TEMPERATURE

Salting

Three different salting practices were compared in cars with similar loads (table 2, cars 3, 5, and 7). The usual salting practice for lettuce shipped during the summer is to add 2 percent of the bunker capacity at initial icing, and 3 percent of the amount of ice supplied at each re-icing. This salting procedure was used as a check treatment (car 3). A heavier salting schedule of 3 percent initial salt and 5 percent at each re-icing was also tested (car 5). A third treatment was included in which salt was added at the fixed rate of 200 pounds initially and 100 pounds at each re-icing (car 7). This schedule would provide the heaviest salting in transit.

Lettuce temperatures.--Although the average temperature during the entire trip of the lettuce in these cars was in a desirable range (table 3), lettuce temperatures became dangerously low in car 7 after 2 saltings of 100 pounds each at Roseville and Sparks (fig. 1). Consequently no salt was added to this car at Ogden and only 50 pounds were added at

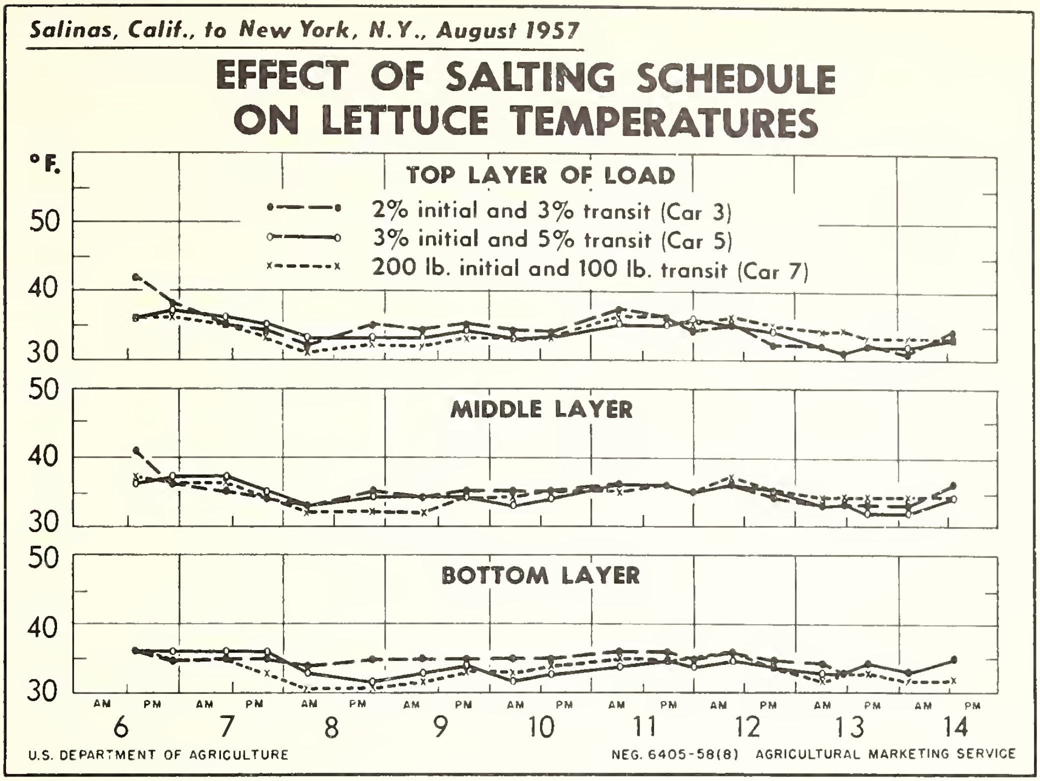

Figure 1

each re-icing between Ogden and Blue Island (table 5). Despite this precaution slight freezing occurred at the bottom bunker position of the load. Lettuce temperatures also became dangerously low at times in the cars receiving either 3 or 5 percent salt in transit, which indicated some risk of freezing even with the lightest salting schedule used in the test.

Air temperatures.--Subfreezing air temperatures occurred near the floor of the 3 cars while they stood at Salinas with fans inactive (table 4). During this period temperatures fell to 28° and 27° F. in cars 3 and 7, which were initially salted with 230 and 200 pounds, respectively (approximately 2 percent of bunker capacity). Temperatures fell to 23° in car 5 which was initially salted with 345 pounds (3 percent of bunker capacity). The danger of freezing the lettuce in the bottom layer of the load was accentuated by such presalting at the rate of 3 percent of the bunker capacity.

After departure from Salinas the temperature of the bottom air was raised by the action of the car-fans to an average of 34° F. with a 3 percent resalting schedule (car 3), compared to 32° with a 5 percent schedule (car 5). However, during long stops enroute, bottom air temperatures dropped again to subfreezing levels while the fans were inactive. Minimum bottom air temperatures in transit ranged from 26° to 30° in these cars at such stops (table 4).

In contrast with bottom air temperatures, the top air temperature in fan cars is relatively high during train stops when the fans are normally off and low between stops when the fans turn as a result of the movement of the train. Although average air-blast temperatures for the entire trip ranged from 33° to 35° F. in the 3 cars, there were times in each car when the air blast dropped below the freezing point of lettuce (table 4). Such temperatures occurred soon after salt was added at a re-icing station. At these times the coldest air blast followed the heaviest application of salt.

Table 2.--Loading data and protective services for test cars of lettuce, Salinas, Calif., to New York, N. Y., August 1957[1]

Car			Container		Load		Salting[2]		Shipper
Test car No.	Pacific Fruit Express No.	Type	Type	No. per car	Shipping weight	Pattern	Initial	Each re-icing	
					Pounds		*Percent*	*Percent*	
1---	8259	40' ice bunker, electric fan.	Carton	552	23,736	Solid	2	3	Royal Packing Co.
2---	8962	40' ice bunker, electric fan.	Carton	764	32,852	Solid	2	3	Harden Farms.
3---	8214	40' ice bunker, electric fan.	Carton	640	27,520	Solid	2	3	Salinas Marketing Coop.
4---	9524	40' ice bunker, electric fan.	Carton	610	26,230	Chimney	2	3	Merrill Packing Co.
5---	8067	40' ice bunker, electric fan.	Carton	640	27,520	Solid	3	5	Harden Farms.
6---	9350	40' ice bunker, electric fan.	Wirebound crate.	600	25,800	Solid	2	3	Salinas Valley Veg. Exchange.
7---	8278	40' ice bunker, electric fan.	Carton	640	27,520	Solid	([3])	([4])	Bud Inc.
8---	300704	50' mechanical	Carton	928	39,904	Solid	None	None	Bruce Church Inc.
9---	300331	50' mechanical	Carton	947	40,721	Solid	None	None	K. R. Nutting Co.
10--	8577	40' ice bunker with thermostat.	Carton	640	28,800	Solid	3	5	Christensen Bros.
11--	8480	40' ice bunker with thermostat.	Carton	638	27,434	Solid	3	5	Salinas Lettuce Farmers Coop.

[1] All ice-bunker cars shipped under full-stage standard refrigeration.
[2] Percent of ice supplied.
[3] 200 pounds of salt added initially.
[4] 100 pounds of salt scheduled for each re-icing but subsequently modified.

Table 3.--Average transit temperatures of layers, stacks, and entire loads of lettuce in test cars, Salinas, Calif., to New York, N. Y., August 1957

Test car No.[1]	Layer[2]			Stack				Load[2]
	Top	Middle	Bottom	Bunker[2]	Quarter-length[2]	Doorway[2]	Quarter-length[3]	
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1-------	37	37	37	36	37	38	37	37
2-------	35	36	36	35	36	36	36	36
3-------	34	35	35	34	35	35	35	35
4-------	36	36	36	35	36	36	38	36
5-------	34	34	34	34	35	34	34	34
6-------	36	36	35	34	36	36	36	36
7-------	34	34	34	32	34	36	36	34
8-------	33	37	37	35	35	37	34	36
9-------	38	40	39	37	40	40	37	39
10------	37	37	36	34	35	40	37	37
11------	36	36	36	35	36	36	36	36

[1] See table 2 for test car treatments.
[2] Near centerline of car.
[3] Near wall of car.

Table 4.--Effect of salting schedule on air temperatures in test cars of lettuce, Salinas, Calif., to New York, N. Y., August 1957

Test car No.[1]	Salting		Air temperature in car				
			Under floor rack			Fan blast in transit	
	Initial	Each re-icing	At Salinas--minimum	In transit			
				Minimum	Average	Minimum	Average
	Percent	*Percent*	°F.	°F.	°F.	°F.	°F.
1-------	2	3	--	--	--	31	35
2-------	2	3	--	--	--	30	36
3-------	2	3	28	30	34	29	34
5-------	3	5	23	26	32	29	35
7-------	([2])	([3])	27	29	33	27	33
10------	3	5	25	24	34	29	36
11------	3	5	24	25	33	28	36

[1] See table 2 for additional information on car treatments.
[2] 200 pounds of salt added initially.
[3] 100 pounds of salt scheduled for each re-icing but subsequently modified.

Between Sparks and Ogden, a run of approximately 26 hours, air-blast temperatures in car 3 dropped gradually to a minimum of 30° F. in 12 hours, after which they started to rise. A similar dip in the temperature of the air blast occurred in car 5 but in this car the minimum reached 29° in about 18 hours. Car 3 received a total of 63 pounds of salt, and car 5 received 135 pounds, at previous re-icings (Roseville and Sparks) (see table 5).

Table 5.--Ice and salt supplied lettuce test cars and estimated ice meltage, Salinas, Calif., to New York, N. Y., August 1957

Date Aug.	Icing station	Time	Test car[1] 1		2		3		4		5		6		7		10		11	
			Ice	Salt	Ice	Salt	Ice	Salt	Ice	Salt	Ice	Salt	Ice	Salt	Ice	Salt	Ice	Salt	Ice	Salt
		PST	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*	*Cwt.*	*Lb.*
6	Salinas, Calif.	1:00 a.m.	115	230	115	230	115	230	115	230	115	345	115	230	115	200	115	345	115	345
7	Roseville, Calif.	9:30 a.m.	6	18	8	24	10	30	8	24	12	60	24	72	6	100	8	40	12	60
7	Sparks, Nev.	9:00 p.m.	7	21	10	30	11	33	7	21	15	75	8	24	7	100	13	65	16	80
8	Ogden, Utah	10:30 p.m.	6	18	7	21	7	21	7	21	10	50	9	27	9	0	7	35	8	40
		MST																		
9	Laramie, Wyo.	7:00 p.m.	8	24	10	30	10	30	11	33	14	70	12	36	8	50	9	45	7	35
		CST																		
10	Co. Bluffs, Iowa	2:00 p.m.	5	15	7	21	6	18	10	30	8	40	12	36	7	50	6	30	6	30
11	Savanna, Ill.	6:00 p.m.	5	15	12	36	14	42	11	33	17	85	11	33	13	50	16	80	13	[2] 130
12	Blue Island, Ill.	4:30 a.m.	9	27	12	36	10	30	12	36	12	60	14	42	10	100	12	60	10	50
		EST																		
12	Windsor, Canada	10:30 p.m.	20	60	16	48	22	66	22	66	24	120	28	84	20	100	18	90	20	100
13	Wayneport, N. Y.	12:00 noon	10	30	14	42	10	30	10	30	14	70	12	36	12	100	10	50	10	50
14	New York, N. Y.	5:00 a.m.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total supplied-------------------			191	458	211	518	215	530	213	524	241	975	245	620	207	850	214	840	217	920
Remaining in bunkers (estimated)--			105	--	100	--	100	--	105	--	100	--	106	--	103	--	97	--	103	--
Total meltage--------------------			86	--	111	--	115	--	108	--	141	--	139	--	104	--	117	--	114	--

[1] See table 2 for salting schedules.
[2] 10 percent salt supplied in error.

In comparison, the air blast in car 7, in which a total of 200 pounds of salt was added at Roseville and Sparks, dropped rapidly to 28° F. and remained between 27° and 28° for approximately 12 hours before the maximum effect of the salt wore off. Between Savanna, Ill., and New York City, a transit period of approximately 2-1/2 days during which ice and salt were added at intervals of 10 to 17 hours, air-blast temperatures became progressively lower between stations and leveled off at 30° in car 3 (3 percent salt), 29° in car 5 (5 percent salt), and 28° in car 7, which received 50 pounds of salt at Savanna and 100 pounds at each re-icing thereafter.

These data show that the drop in air-blast temperature following salting is in proportion to the amount of salt added, and that the maximum effect of the salt seems to occur approximately 12 to 18 hours after salting when either the 3 or the 5 percent salting schedule is followed.

Ice meltage and salt depletion.--Depletion of salt in the bunkers after resalting was reflected in the salinity of the water draining from the ice bunkers. Salinity remained near the percentages specified in the salting schedule or at a higher level (due to carry-over from previous saltings) for a longer time after salting when cars remained standing than when they were in motion (table 6).

Table 6.--Effect of salting in transit on salinity of water from bunker drain, Salinas, Calif., to New York, N. Y., August 1957

Date August	Salting station	Sampling station	Hours from last salting	Salt in drain water: 3 percent salting schedule (car 2)	Salt in drain water: 5 percent salting schedule (car 5)	Train operation
				Percent	*Percent*	
9	Laramie	--	--	--	--	Moving
9	--	Cheyenne	3.5	3.6	4.8	Moving
10	--	N. Platte	10.5	1.7	3.7	Moving
10	--	Grand Island	14	0.6	1.6	Moving
10	Council Bluffs	--	--	--	--	Standing
10	--	Council Bluffs	6	4.1	6.5	Standing
11	--	Council Bluffs	16.5	2.9	4.9	Standing
11	--	Savanna	28	0.3	0.3	Moving
12	Blue Island	--	--	--	--	Standing
12	--	Blue Island	5	6.6	6.6	Standing
12	--	Detroit	10	4.0	3.3	Moving
13	Wayne-port	--	--	--	--	Moving
14	--	N. Y. City	17	1.4	2.4	Moving

At arrival in New York, 17 hours after the previous salting, salt concentrations in the drain water were approximately one-half those called for by the schedule.

When a schedule specifying 2 percent initial salt and 3 percent at each re-icing (car 3) was used, a total of 530 pounds of salt was supplied and 11,500 pounds of ice was melted (table 5). With the 3 and 5 percent schedule (car 5), 975 pounds of salt was used and 14,100 pounds of ice was melted. However, meltage of 2,600 more pounds of ice in car 5 than in car 3 resulted in a difference of only 1° F. in the average transit temperature of the loads. This fact illustrates the importance of good precooling of lettuce as it would be difficult to complete the precooling of the lettuce in transit in the present type of load even with a heavy salting schedule.

Size of load

The effect of size of load on transit temperatures of lettuce was compared in 3 regular 40-foot ice bunker cars, each of which received the same salting schedule (table 2). The loads tested were a light load of 552 cartons (car 1), a heavy load of 764 cartons (car 2), and a standard load of 640 cartons (car 3). Loading patterns were kept as similar as possible, but in the heavy load it was necessary to stack the cartons 5 high on-side with a partial sixth layer that consisted of 2 rows in which the cartons were placed crosswise, on-side and in line with the spaces between the fan openings.

At the shipping point, average load temperatures were similar in the 3 cars (38° to 40° F. after precooling). During most of the transit period, average lettuce temperatures in top, middle, and bottom layers usually were slightly higher in the light load (car 1) and slightly lower in the standard load (car 3) than in the heavy load (car 2) (fig. 2 and table 3). Because of a short delay at loading, initial temperatures in the light load were slightly higher than in the other 2 cars. However, average transit temperatures of

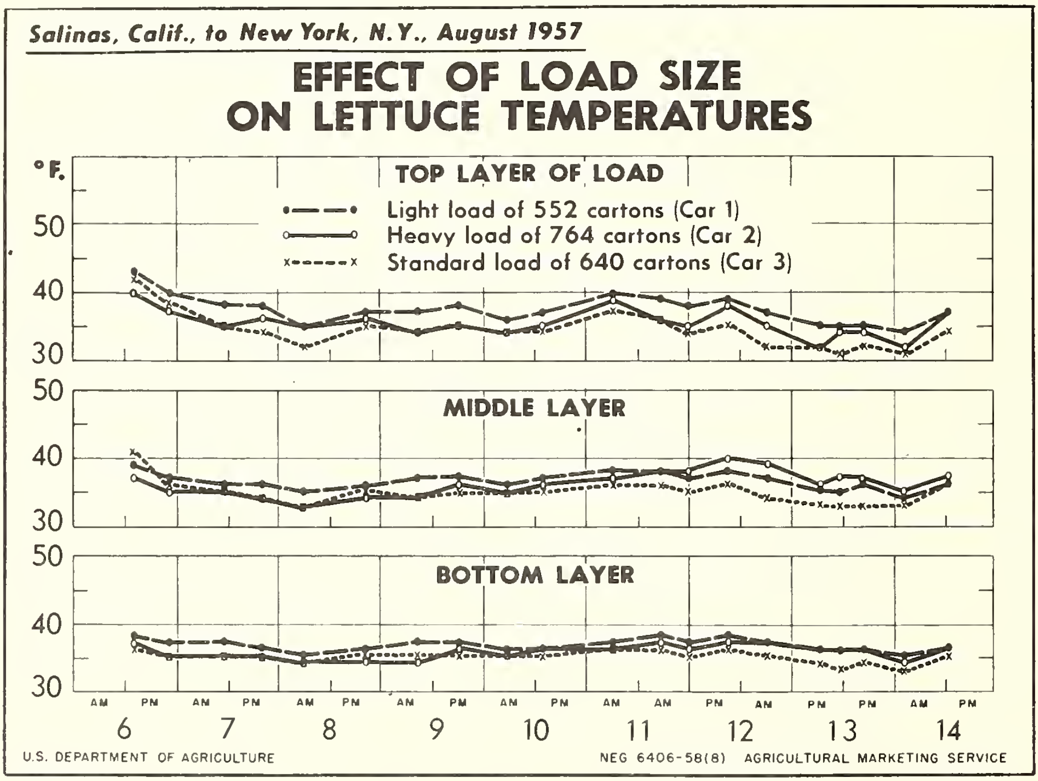

Figure 2

the 3 loads varied by only 2 degrees. All the lettuce arrived in good condition. There was slight compression of the cartons in the bottom layer of the heavy load, but it was of no commercial significance. Heavy loading of 40-foot cars seems feasible under prevailing protective services if the lettuce is well precooled.

Loading Pattern

Loading patterns compared were a solid (conventional) load and a chimney load. In the solid load (car 3) the cartons were set lengthwise of the car, on-side, in 8 rows for the first 4 layers and in 4 rows on-bottom in the fifth layer, leaving a lengthwise channel in the center of this layer. With this loading pattern 640 cartons were placed in the car. In the chimney load (car 4) the cartons were set on their sides crosswise and lengthwise of the car in groups of 4 per layer, each group making a column with a vertical air channel or chimney through its center approximately 10 inches square. This load was 5 layers high, contained a total of 610 cartons, and had 22 chimneys. Both cars were shipped under the same salting schedule (table 2).

Lettuce temperatures during transit were slightly higher in the top layer of the chimney load than in the conventional load (fig. 3). However, the average temperatures of the loads for the entire trip (35° to 36° F.) were satisfactory in both cars (table 3). This indicates that circulation of cold air was adequate in either load.

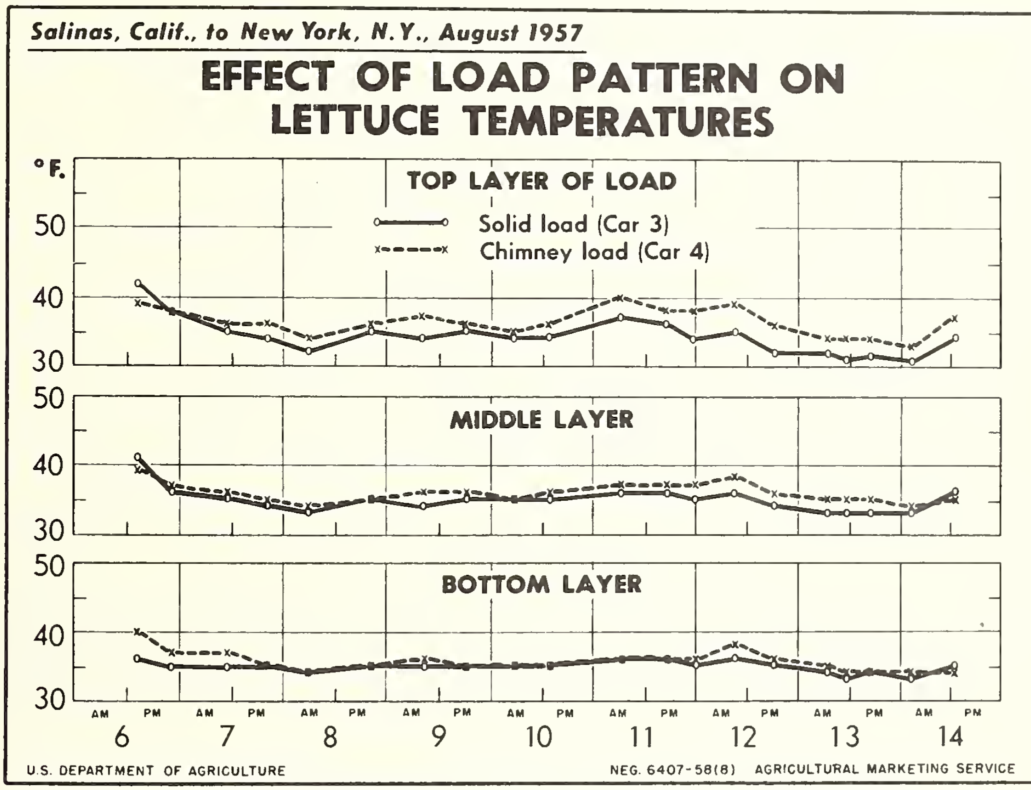

Figure 3

There was no difference in breakage of cartons or bruising of lettuce in the 2 types of loads and no freezing was observed in either car. However, the solid load had advantages over the chimney load with respect to ease of handling.

Type of Container

Since freezing is sometimes a problem in transcontinental shipments of California lettuce, a comparison was included to determine if the type of container in which the lettuce was packed had an effect on transit temperatures. The types of containers compared were the carton (car 3) and the wirebound crate (car 6). Salting schedules were the same in the 2 cars and loads were approximately the same size (table 2).

The transit temperatures of the lettuce in cartons and crates were nearly the same in the bottom and middle layers of the loads, but the lettuce in the top layer averaged approximately 2 degrees cooler in the carton load than in the crate load (fig. 4 and table 3).

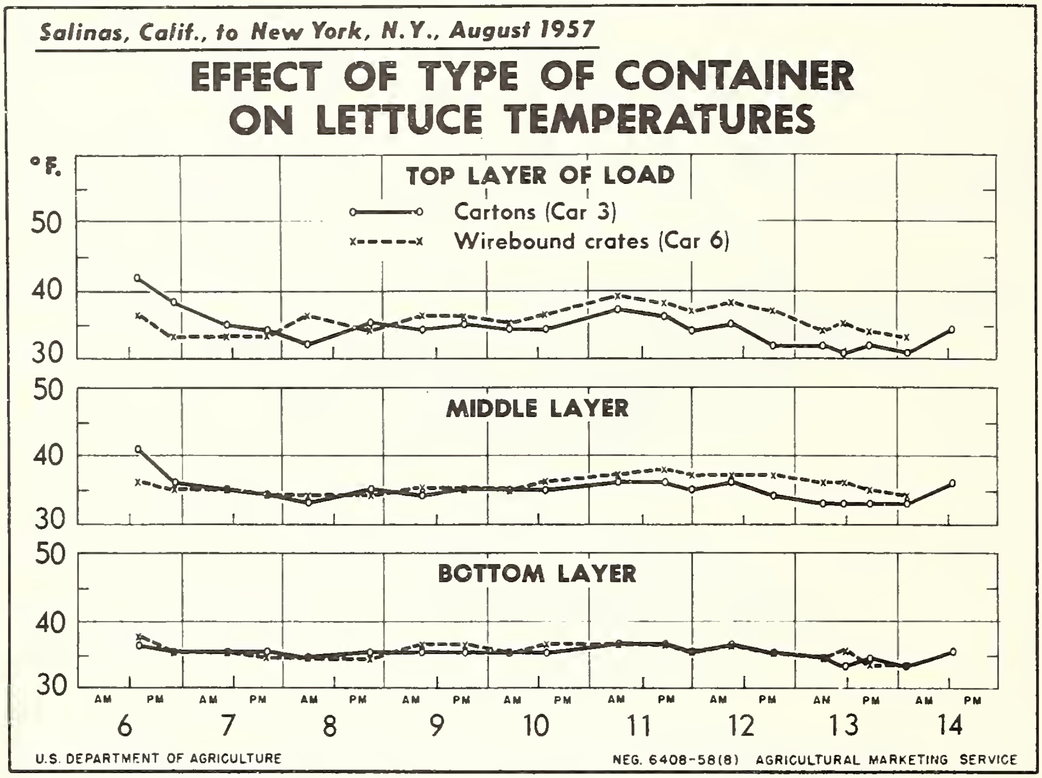

Figure 4

Although the average transit temperature of the lettuce in the bunker stacks was 34° F. in both loads (table 3), slight freezing was observed at destination in lettuce at the bottom bunker position in the crate load while no freezing was observed in the carton load. Freezing in the crate load, which may have been due to the openness of the crates, indicates that less salt may be advisable for lettuce shipments in crates than for those in cartons.

Thermostatic Control of Fans in Ice-Refrigerated Cars

Two of the ice-bunker cars were equipped with thermostats to control the electric fans as described by McKillop et al.[4] These cars were compared with a conventional electric fan car (car 5) to determine if they would reduce the danger of freezing when a heavy salting schedule of 5 percent in transit was used.

[4] McKillop, A. A., Morris, L. L., and Barger, W. R. Thermostatic control for fresh perishables in ice-refrigerated railroad cars. Industrial Refrigeration. Nov. 1957.

In one of the cars the thermostat controlled all the fans, and dampers were used to close the fan openings when the fans were not running (car 10). In the other car, the dampers were omitted and the thermostat was connected to the 4 corner fans only, leaving the center fan in each bunker to operate normally (car 11). The thermostats were set at 33° F. and the sensing elements were inserted in heads of lettuce in the top layers of the loads. Loads were similar in size and pattern and the cars were shipped under the same salting schedule (table 2).

Lettuce temperatures were held at a satisfactory level (below 38° F.) in all cars during most of the trip but they dropped closer to the freezing point in the conventional car (car 5) than in the cars equipped with thermostats (fig. 5). The average transit temperature of the entire load was 2 to 3 degrees cooler in the conventional car than in the thermostatically equipped cars (table 3).

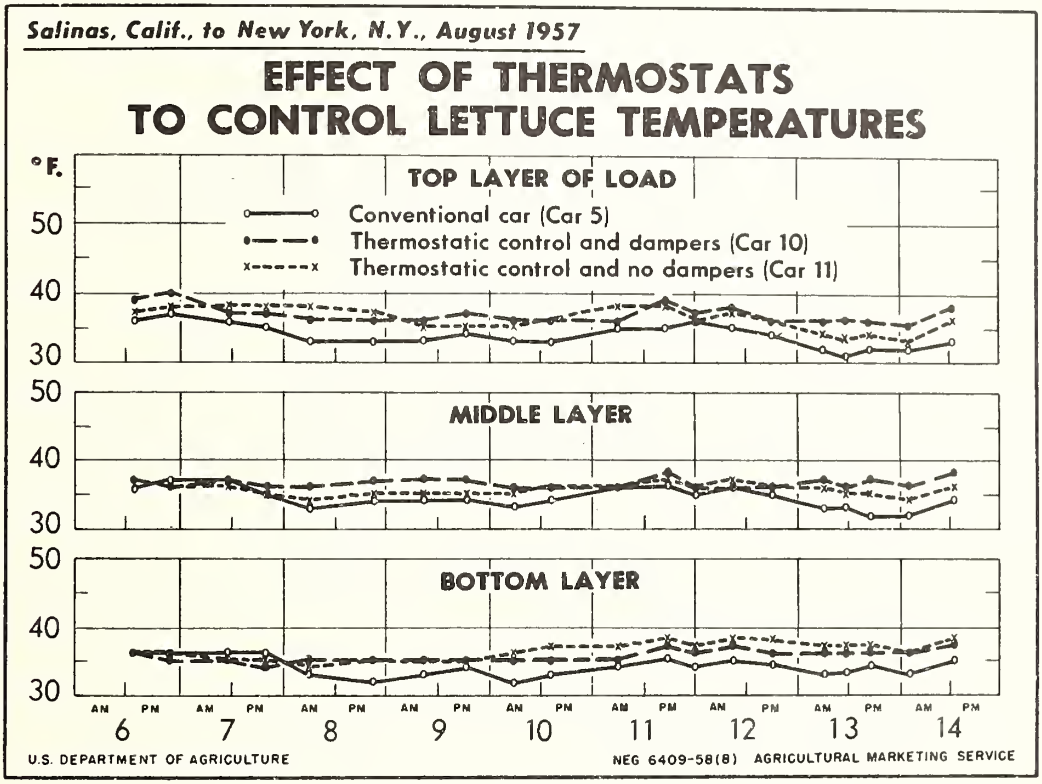

Figure 5

Although average air temperatures during the transit period were only slightly lower in the conventional car than in the cars with thermostatic controls, at times the minimum temperatures were much lower in the conventional car. For example, during a layover of approximately 18 hours at Council Bluffs the air temperature under the floor racks in the conventional car dropped 5 degrees in the first 8 hours to a dangerous low of 26° F. and remained at subfreezing levels for the remaining 10 hours of the layover. In comparison, air temperatures near the floor of the 2 cars with thermostats did not drop below 32° during the same layover. This temperature was reached in 16 hours in the car with dampers and in 8 hours in the car without dampers.

Under the conditions of this test, thermostatic controls reduced excessive cooling of the lettuce in transit when a heavy salting schedule was followed, and the use of dampers helped to prevent or delay the occurrence of subfreezing air temperatures near the floor of the car during layovers.

Mechanical Refrigerator Cars

Two 50-foot mechanically refrigerated cars were used to determine their usefulness for lettuce. Both cars were of the envelope design with the cold air circulating through the walls, ceiling, and floor without entering the load compartment. One car (car 8) was equipped with electric fans set in a false bulkhead in each end of the car to circulate the air in the load compartment, while the other (car 9) was without fans. The thermostats were activated by the temperature of the air in the envelope and were set at 33° F.

In the mechanical car without fans, the temperature of the lettuce in each layer gradually increased during the transit period. The temperature of the lettuce in the mechanical car with fans gradually decreased for the first 2 days in transit and then remained constant for the remainder of the transit period (fig. 6). This resulted in average transit temperatures of 36° F. for the load in the car with fans (car 8) and 39° in the car without fans (car 9). In contrast, the average temperature of the load in a conventional ice bunker car (car 3) shipped under 2 and 3 percent salt was 35° F. (table 3).

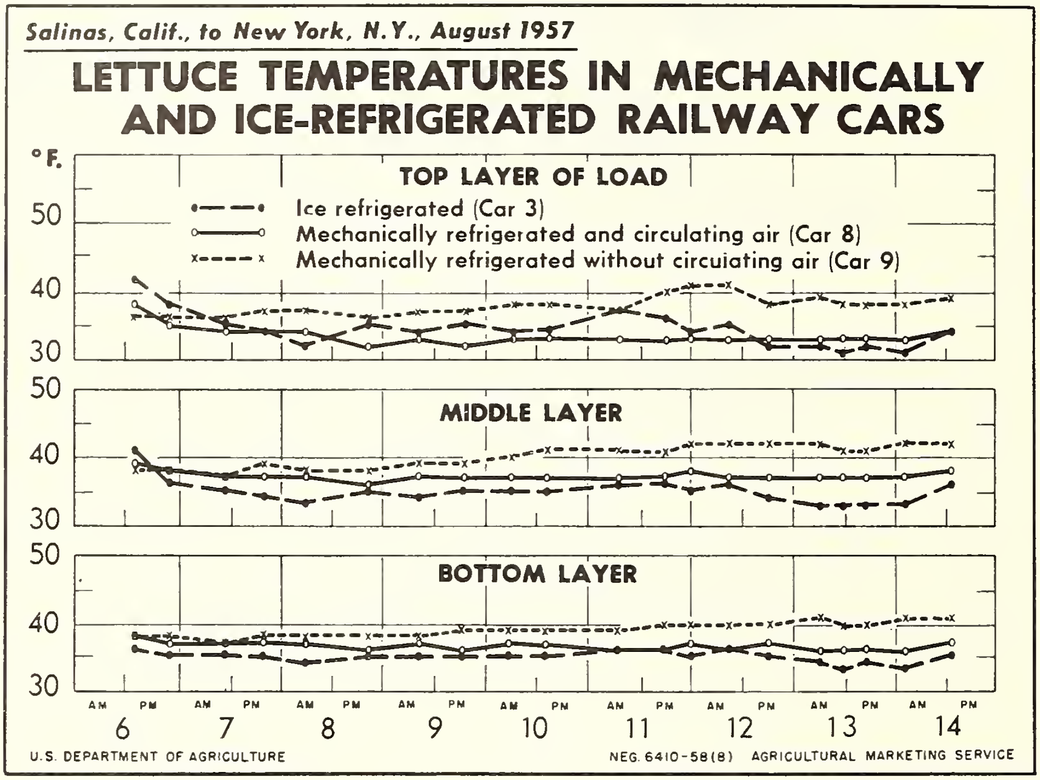

Figure 6

Forced air circulation in the load compartment of the mechanically refrigerated car containing fans improved the transit temperature of the lading by maintaining temperatures close to the thermostat setting. It also reduced the condensation of moisture on the walls and ceiling, which commonly occurs in still-air envelope type cars.

The relative humidity of the air above the load ranged from 75 to 100 percent and averaged 90 percent in the mechanically refrigerated car with air circulation (car 8). The relative humidity in 2 ice bunker cars shipped with 5 percent salt in transit fluctuated between 60 and 80 percent and averaged 73 percent. No wilting of the lettuce was evident in any of these cars.

These results indicate that mechanical refrigerator cars are suitable for precooled lettuce and that air circulation within the load compartment is advisable for this commodity.

RELATION OF TEMPERATURE TO MARKET QUALITY OF LETTUCE

The test lots of lettuce were examined at New York to determine the effect of transit temperature on the development of various disorders (table 7). The average transit temperature of the lettuce in the test cartons was 35.5° F. (34.8 to 36.1°) in 4 cars and 40.9° (38.8° to 42.4°) in 4 others. For purposes of comparison these test lots were grouped according to the following means. The test lots from the remaining 3 cars were not included since they fell into an intermediate temperature of 37°.

Table 7.--Effect of transit temperature on condition of lettuce at destination, Salinas, Calif., to New York, N. Y., August 1957

Factors studied	Average transit temperatures[1]	Heads affected	
		At arrival	After 3 days at 70° F.
	°F.	*Percent*	*Percent*
Marginal browning (untrimmed heads)	35.5	0	65.6
Do	40.9	0	67.7
Decay-external (untrimmed heads)	35.5	4.2	66.7
Do	40.9	4.2	81.3
Decay-internal	35.5	0	4.2
Do	40.9	1.0	6.3
Mild russet spotting	35.5	10.4	11.5
Do	40.9	5.2	14.6
Severe russet spotting	35.5	3.1	1.0
Do	40.9	2.1	7.3

[1] Average transit temperature of test packages in 4 cars (see text).

General appearance.--The general appearance of the lettuce was rated on a scale of 1 through 9 in which 9 represented field freshness, 7 good, 5 fair, 3 poor, and 1 nonsalable. At arrival there was no apparent difference in general appearance between the lettuce shipped at the cooler temperatures and that shipped at the warmer temperatures. Both groups were rated as good to fair before trimming. After 3 days at 70° F. differences in general appearance still were not apparent between the 2 groups, but all the lettuce had deteriorated to a rating of fair to poor. Ratings of the samples held at Davis for a simulated transit period were similar to those obtained at New York.

The lack of differences in general appearance of the various test lots of lettuce is attributed to the relative shortness of the transit period and the narrowness of the range of temperatures obtained.

Marginal browning.--Marginal browning of the leaves of untrimmed heads was not influenced by the transit temperatures. Marginal browning was not apparent in either temperature group at time of arrival, but after 3 days at 70° F., marginal browning was developing in both groups on two-thirds of the heads.

Decay.--Decay evident in untrimmed heads averaged 4 percent in both groups at time of arrival. However, after the 3-day storage period at 70° F., 81 percent of the heads shipped at the warmer temperatures showed decay compared to 67 percent of those shipped at the cooler temperatures.

Trim loss.--Following external examination, each head was trimmed to simulate retail display. The percentage of weight lost by trimming was not affected by the transit temperature nor by the 3-day storage period at 70° F. The weight lost from trimming averaged approximately 35 percent.

Russet spotting.--No relation was apparent between the transit temperatures obtained in this test and the amount of russet spotting at time of arrival. However, after 3 days at 70° F., both mild and severe spotting tripled in the lots with transit temperatures averaging 40.9°, while no appreciable increase occurred in the lots averaging 35.5°.

In the lettuce held at Davis under simulated transit conditions the occurrence of russet spotting was similar to that found at New York. After an 8-day simulated transit period the lettuce did not show russeting at 32° F. and showed only a small percentage at 41°. After an additional 2 days' storage at 68°, little change occurred in the lettuce "shipped" at 32° whereas one-fourth of the heads "shipped" at the warmer temperature showed russeting.

Indications from the present tests are that lettuce shipped at the higher temperatures develop more decay and russet spotting after arrival at eastern markets than lettuce shipped at the lower temperatures.

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